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FLOOD RISK PATTERN RECOGNITION IN RAJANG RIVER BASIN, SARAWAK

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ABSTRACT:
Flood is one of the natural disaster events in Malaysia. The flood occurred due to overflow of the excessive water level in the river system which causing land sinking and major disruption towards the human and environment. The objective of this study is to evaluate the flood risk index in the Rajang River Basin. A set of the database from 1989-2019 were gathered from Department of Irrigation and Drainage (DID) and were analysed using Principal Component Analysis (PCA), Statistical Process Control (SPC) and Flood Risk Index (FRI). The application of statistical process control (SPC) had revealed the most the significant factors of flood occurrence by using principal component analysis (PCA) in Rajang River Basin through water level prediction at the study area by determining the control limit value. Water level prediction helps to develop the flood risk index (FRI) which can show the current and future prediction in the Rajang River Basin, also helps the local authorities for flood control, and reduce the impact of flood in Sarawak. Based on the findings, the most significant factors identified for the occurrence of flood in the Rajang River Basin are water level, rainfall, and evaporation, which eventually lead to high increases in water level. In conclusion, uncontrolled deforestation due to rapid development in the upriver areas also have worsened the flood occurrence situation even worse.

INTRODUCTION

Flood is one of the natural phenomena in Malaysia that occurred when the river bursts its banks and cause the water to spills out due to the heavy rains (Zainal & Doraisamy., 2015). In Malaysia, including Sabah and Sarawak, there is a total of 189 river basins with 89 of the river basins are in peninsular Malaysia, while 78 in Sabah and 22 in Sarawak, with 85 of the river basins are prone to become recurrent flooding areas (Abdullahi, 2014). According to D/iya et al., (2014), 9% of the total Malaysia areas are flood-prone area, which affected almost 4.82 million people (22%). Therefore, effective prevention measures need to be taken by the authorities to manage flood occurrence in Malaysia. According to Doocy et al. (2013) and Supattra et al. (2014), few factors contributed to the flooding problem including topography, geomorphology, drainage, engineering structures and climate change. Human activities such as an unplanned rapid settlement development and extreme changes in land use are contributing much towards the pattern of the flood. Doocy (2013) also explained that floods mostly are known to be caused by the storms, in which a lot of precipitation or substance falls in a short period. The flood had greatly affected the physical environment, economic and health of the community. According to a report by Asia One (2015), the 2014 flood in Malaysia has been described by the Malaysian Insider as the worst floods occurred in decades as more than 200,000 Malaysians been affected with the flood while 21 people lose their life. The damages caused by this flood has badly affected the community by the destruction of houses and other infrastructures (Akasah et al., 2015). In addition, according to DID (2017), the existing flood control warning systems in the country are still inadequate to face the future impact of floods. Therefore, this study conducted was to improve the current flood control warning system by using the flood risk index. The objective of this research was to evaluate the flood risk pattern recognition in the Rajang River Basin, Sarawak. The specific objectives were to determine the significant factors of flood occurrence in Rajang River Basin, to analyse control limit for the water level in Rajang River Basin and to develop the flood risk index (FRI) to determine the level of risk for flood in Rajang River Basin, Sarawak. The research hypothesis stated for this research was there are significant correlations between the hydrological factors; water level, rainfall, and evaporation that contribute to flood occurrence in Rajang River Basin. Second, there are significant variables with accurate control limit for flood alert in Rajang River, Sarawak. For the third hypothesis was there is a significant level of risk based on the flood risk index developed in the Rajang River Basin.

METHODOLOGY

Study Design

This study was conducted by using a multivariate statistical analysis, which known as the chemometrics technique. Chemometrics technique was based on the multivariate statistical principles, in order to develop the flood risk index for the study area. Chemometrics techniques that had been applied in the study included Principal Component Analysis (PCA), Statistical Process Control (SPC) and Flood Risk Index (FRI).

Study Area

The study focusing on Sarawak located between (Latitude: 0° 50’ and 5° N; Longitude: 109° 36' and 115° 40' E). It extends along the northwest coast of Borneo for about 800 kilometres, covering an area of 124,449.51 square kilometres. The state is separated by a distance of 600 kilometres from Peninsular Malaysia by the South China Sea. Inland, Sarawak borders with Kalimantan, Indonesia. Sarawak is divided into three areas, which are coastal lowlands containing peat swamps as well as narrow deltaic and alluvial plains, a wide area of roughly 300 meters of undulating hills, and the mountain highlands extending to the Kalimantan frontier. As Batang Rajang River is Malaysia’s longest river, thus it is divided into 21 river basins; Kayan, Sg Sarawak, Samarahan, Sadong, Lupar, Krian, Saribas, Oya, Mukah, Balingian, Tatau, Kemena, Similajau, Suai, Sibuti, Niah, Baram, Limbang, Lawas, Trusan and Upper and Lower Rajang river basins (Ishamudin, 2006). In addition, Rajang River Basin has been divided into two, which are Upper and Lower Rajang Basins due to the large area of the size of the river that covered until 47,880 square kilometers.

Data Collection

Thirty years of hydrological data in Sarawak’s flood-prone area dated from 1989 to 2019 containing the total number of 1,036,800 data obtained from DID were analysed in this study. The data consist of three parameters, which are water level, rainfall and evaporation.

In the study, the data collected been analysed by using the XLSTAT Base 2020 add-in software for integrated chemometrics techniques. The total number of data obtained is 24 099 and it contains some missing values. Hence, to predict the unknown or missing value, the principle of the nearest neighboring method was used, by referring to the known value of the nearest neighboring location. Chemometrics technique is utilising the application of Principle Component Analysis (PCA) and it can be used to identify the reduction of the variables into a set of the factors for further analysis. This method also used to compare the sets of data and identifies the effect of the most changes in hydrological modelling in the study area (Saudi et al., 2015).

The second technique used in this study was the application of Statistical Process Control (SPC). SPC techniques were used to analyse the water level pattern in the study area. Through this method, the process is starting from evaluating analysed data efficiently from the performance. It produced three results that are important in hydrological modelling predictions; which are Upper Control Limit (UCL), Average Value (AVG), and Lower Control Limit (LCL). The UCL value is considered an intolerable value for a variable and treated as a high- risk condition for flood (Saudi et al., 2018).

Flood Risk Index (FRI) was the last chemometrics technique being applied. FRI is an advanced computer modelling and simulation is required to acquire an accurate flood prediction. Flood risk model has been created based on a combination of several types of multivariate analysis and SPC. The flood risk index in this study been categorized into the level of risk numbering from 0-100 where the range of; 70 to 100 is considered as high risk index, 35 until 69 is moderate risk index and 0 till 34 is low risk index. The selection of range 70-100 was based on the Relative Strength Index (RSI), where 70 and above is considered as an upper bound and an intolerable condition (Saudi et al., 2015). The process of creating this flood risk index undergone few processes of statistical analysis. First, a suitable variable will be selected by PCA. The variables with the highest correlation coefficient are the next pick for the upcoming process in the analysis state. After the selection of variable completed, the determination for control limit value was being conducted by implementing the SPC techniques. For the flood risk index, the UCL value from SPC was used to build a flood risk model.

RESULTS AND DISCUSSION

A total set of 30 years data from 1989 until 2019 in Rajang River Basin were analysed using XLSTAT Software as mentioned in the previous chapter. Three hydrological parameters selected are rainfall, water level and evaporation. These variables being analysed for the statistical analysis by using the normality test, descriptive analysis, PCA, and SPC.

Factors contribute to flood occurrence in Rajang River Basin

Principle component analysis (PCA) was used to determine the significant parameter of the flood occurrence as mentioned in the first objectives of this study. According to Fahmi et al. (2012), only strong factor loadings were selected for the principal component (PC) construed. Varimax factor (VF) were generated as the rotation process was applied by using the selected principal component (Saudi et al., 2014). From the result findings in Table 1, the result showed that F1 (1.294) were gained as the eigenvalue, more than (>1) and the variability percentage of this factor was 43.132%. F1 in this study is referring to water level, F2 is rainfall and F3 is evaporation parameter. Therefore, the principal component that was selected for the varimax rotation process is F1 as it represents the higher number of eigenvalue reading. This proved that water level is the most significant parameter that contributes towards the flood occurrence. According to Azid et al. (2015), PCs with the eigenvalues less than (<1) were neglected due to the redundancy with the main factors.

Table 1: Eigenvalue for factors from PCA

	F1	**F2**	**F3**
Eigenvalue	**1.294**	0.947	0.759
Variability (%)	**43.132**	31.571	25.297
Cumulative %	43.132	74.703	100.000

*Eigenvalue more than (>1.0)

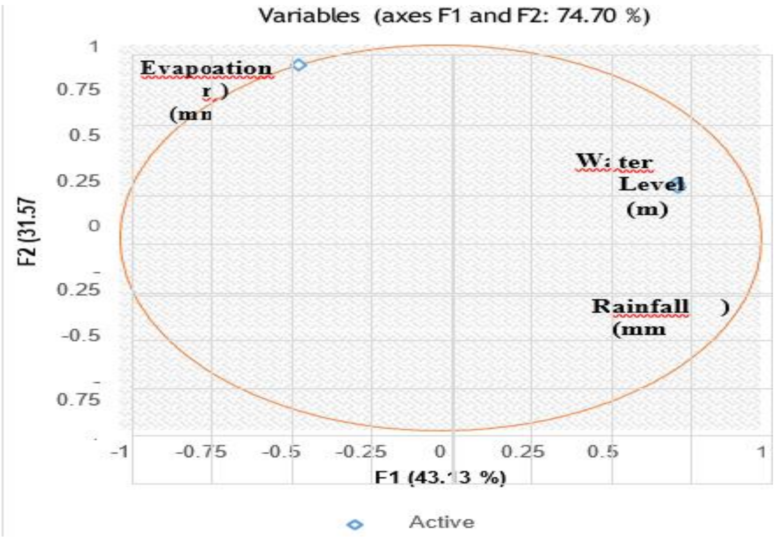

Figure 1: Factor loadings after varimax rotation

Hydrological parameters pattern

Referring to Figure 2, further analysis as the second objective in this study is to analyse the hydrological movement pattern and risk of flood in the Rajang River Basin. Therefore, SPC was conducted through the control chart in order to set the control limit for flood prevention and mitigation measures in the study area. The main factors that were chosen as the most crucial contributor to the flood occurrence in the study area were the water level. In order to stimulate the emergency response action by the authority, the limitation must be cleared. The exceeding water level would trigger the flood occurrence as Sarawak experiences an annual rainfall around 3,000 mm to 4,000 mm continuously and this can lead to flash flooding phenomenon (Abdullahi, 2014). Figure 2 showed that the control limit for the water level is 5.967 mm with the upper control limit (UCL) is 6.890 mm, lower control limit (LCL) is 5.044 mm and the average control limit (AVG) is 5.967 mm respectively. Readings that had exceeded the UCL reading is considered as high risk for flood occurrence. While all the data recorded below the LCL is considered drought or high level of flood risk. According to Abdullah (2015), flood resulting in increasing of potential health impacts such as waterborne diseases and lack of clean water supply for the community.

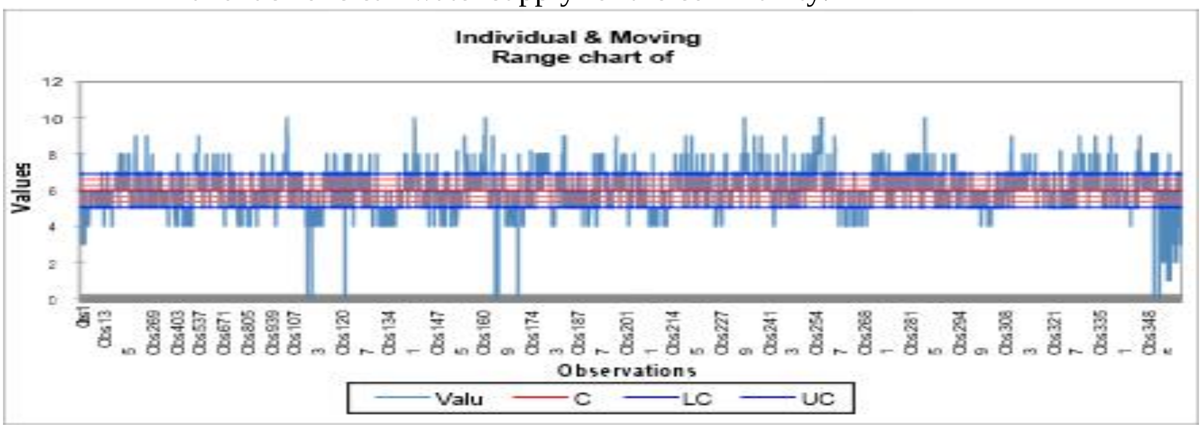

Figure 2: SPC graph on water level pattern

Flood Risk Index (FRI) of Rajang River Basin

The control limits value in the previous SPC analysis were derived to perform the risk index classification, as it is important to classify the actual flood risk level for Rajang River Basin.

Hence, the FRI analysis was the last step needed for the data analysis. The flood risk index in this study was ranging from 0-100 where the range of; 70 to 100 classified as high risk index, 35 until 69 is moderate or cautionary risk index and 0 till 34 is low risk index. The selection of range 70-100 was based on the Relative Strength Index (RSI), where 70 and above is considered as upper bound and an intolerable condition (Saudi et al., 2015). From Figure 3, the percentage for high risk class with 31.6% from the total result was clearly explained. Medium risk class is at the most with the value of 67.8% following with the low risk class at 0.6%. Hence, the range from flood risk index constructed can help the emergency response team to be ready before massive destruction happened (Saudi et al., 2018). Local authorities need to take early emergency response actions starting when the percentage is in the cautionary zone class.

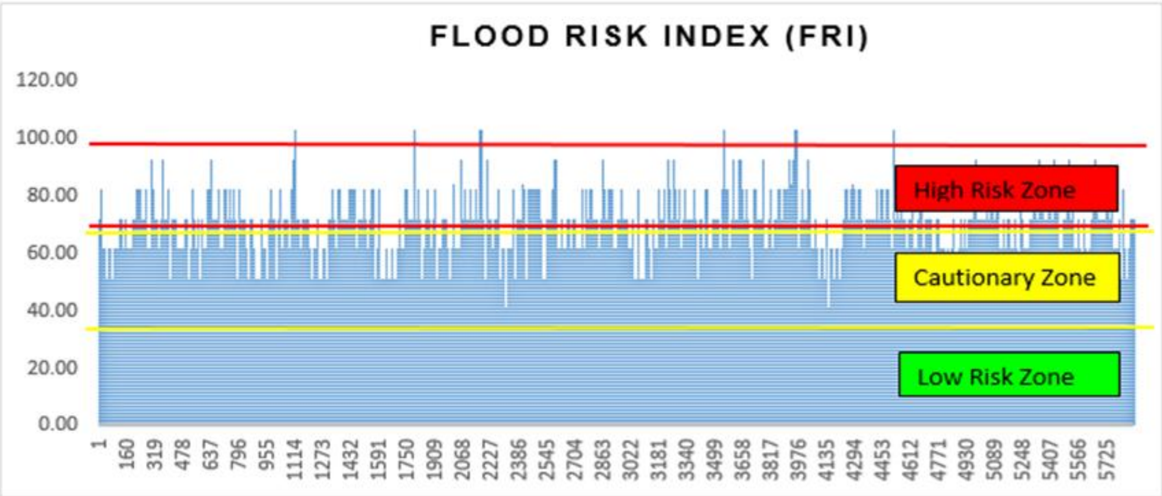

Figure 3: Flood Risk Index performance of Water Level

CONCLUSION

From this study, it is shown that water level was the most contributing factor towards the flood occurrence in the Rajang River Basin, followed by rainfall and evaporation. This proved that water level had an impact on changing the flood pattern occurrence. However, all the parameters are equally important to reduce human life’s loss and properties through this early detection of flood risk pattern. In conclusion, FRI models in this study are significant as the baseline for flood mitigation measures for the local authorities and could bring major positive changes to the global flood issue especially to the flood-prone area.

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